SSBRP USER OPERATIONS FACILITY (UOF) OVERVIEW AND DEVELOPMENT STRATEGY

Lou Picinich [t], Thom Stone [tt], Charles Sun [ttt], and May Windrem [tttt]

NASA Ames Research Center
Building 244 Mailstop 244-19
Moffett Field, California 94035-1000 USA
FAX : +1-650-604-0673, E-mail : [t] *lpicinich@mail.arc.nasa.gov*
[tt] *tstone@mail.arc.nasa.gov* [ttt] *csun@mail.arc.nasa.gov* [tttt] *mwindrem@mail.arc.nasa.gov*

ABSTRACT

This paper will present the Space Station Biological Research Project (SSBRP) User Operations Facility (UOF) architecture and development strategy. A major element of the UOF at NASA Ames Research Center, the Communication and Data System (CDS) will be the primary focus of the discussions.

CDS operational, telescience, security, and development objectives will be discussed along with CDS implementation strategy. The implementation strategy discussions will include: Object Oriented Analysis & Design, System & Software Prototyping, and Technology Utilization. A CDS design overview that includes: CDS Context Diagram, CDS Architecture, Object Models, Use Cases, and User Interfaces will also be presented.

CDS development brings together "cutting edge" technologies and techniques such as: object oriented development, network security, multimedia networking, web-based data distribution, JAVA, and graphical user interfaces. Use of these "cutting edge" technologies and techniques translates directly to lower development and operations costs.

INTRODUCTION

SSBRP's mission is to design, develop, validate, and deploy a facility class payload to perform non-human life science experiments on the International Space Station (ISS). The operation of the facility class payload will be accomplished at the UOF at NASA Ames Research Center, Moffett Field, California, USA. The principal communication and data processing element of the Ames UOF is the CDS which will be featured in this paper.

Figure 1 presents the CDS communication infrastructure for planning, commanding, telemetry processing, and data distribution. Planning consists of pre-increment launch planning and on-orbit activities planning, using CDS planning software and planning systems at other NASA centers. External planning systems include the Payload Planning System (PPS), Payload Data Library, and Payload Information System at Marshall Space Flight Center (MSFC) and the Space Station Payload Processing Facility at Kennedy Space Center (KSC).

Commanding is accomplished through an interface with the Payload Operations Integration Function (POIF) at MSFC and the Space Station Control Center at Johnson Space Center (JSC), Both the MSFC and JSC facilities verify the commands integrity and then integrate the command with other commands for uplink to the ISS.

Telemetry data originates in the SSBRP on-orbit equipment and is transported to CDS via the ISS Communication and Data Handling System and through the MSFC Payload Data Services System. CDS processes the SSBRP data (includes: experiment data, engineering data, and digital video) as real-time broadcast data/video and also stores the data/video for future retrieval and analysis. CDS is required to store, as a minimum, the last 120 calendar days of telemetry data.

Details of the commanding and telemetry architecture may be found in SpaceOps98 paper 2m006 "End-to-End Data System Architecture for the Space Station Biological Research Project".
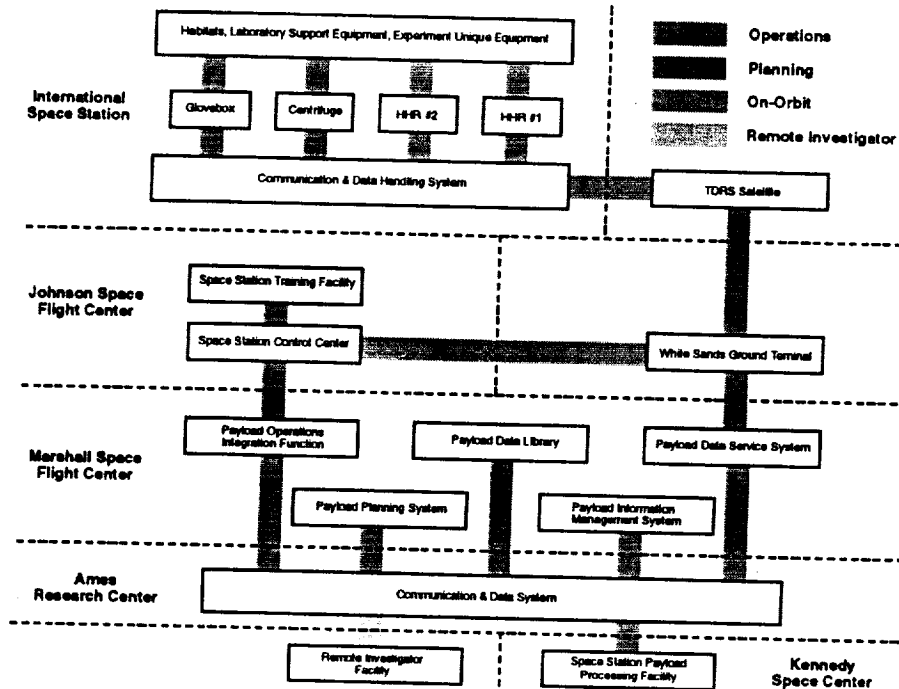
Figure 1 - SSBRP Communication Infrastructure

CDS data and video distribution to researchers not resident within the Ames UOF will be accomplished using Internet/World Wide Web/JAVA technologies. This approach allows platform independence and processing flexibility at the remote researchers facility.

CDS DEVELOPMENT OBJECTIVES

Development objectives fall into one of two categories: mission (both performance and interface) requirements and operational efficiency. CDS mission requirements can be grouped as science, operations, security, and engineering requirements. Table 1 below contains a summary of CDS mission requirements.

Table 1 - CDS Mission Requirements (Summary)

Science

Support Multiple Experiments & Researchers
Provide Habitat Environmental Control
Support Remote Experiment Monitoring
Support Specimen Sharing
Provide Experiment Data Accessibility

Security

Support Distributed Operations
Provide Data Partitioning by Researcher
Perform Internet Data Distribution
Implement Security Policy
Provide Computer/Network Security

Operations

Perform Concurrent Operations(24hrs x 7days)
Perform Integrated Planning
Provide Real-time Data Distribution
Provide Remote Researcher Presence at UOF
Perform Integrated Logistics

Engineering

Provide Equipment Monitor & Control
Support Equipment Diagnostics
Provide Logistics & Inventory
Support Maintenance
Perform Development Verification

The CDS development team has (and will continue to) traded-off one-time development costs versus operational costs as the means to increase operational efficiency. To say this another way, CDS is being developed to eliminate as many operator functions as possible without jeopardizing crew/vehicle/payload safety or mission success. CDS is also developing the user interface to be as intuitive as possible to reduce operator/user training and skill requirements. Figure 2 is an example of the user interface strategy developed during a CDS prototyping activity. The user interface strategy presented illustrates how a user would select an alarm (on the left most display) and navigate to the appropriate display for the user to initiate corrective action (on the right most display). Please also note the integration of data and video on the right most display.
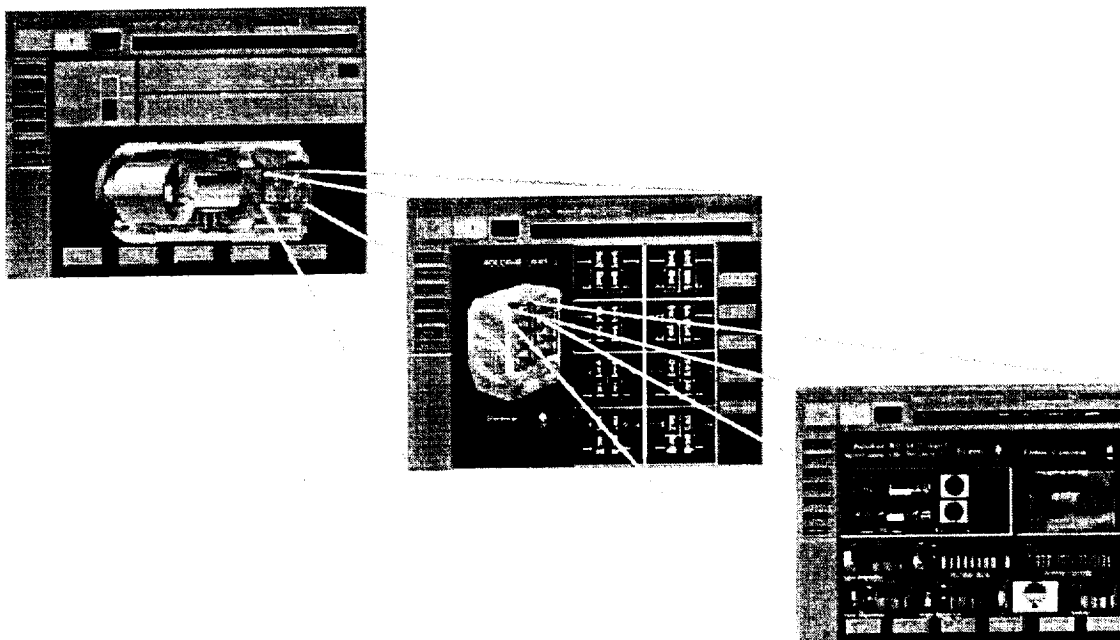

Figure 2 - CDS User Interface Strategy

IMPLEMENTATION STRATEGIES

The overall implementation strategy for CDS was to identify and use wherever possible "cutting edge" technologies and techniques currently available. With the projected ISS life span of 10 years or more, the CDS approach minimizes obsolesce of today's technologies without the need to invent technology. Good examples of these "cutting edge" technologies are: Object Oriented Analysis & Design, JAVA, multimedia data communications, network security, Internet-based data distribution, video multicasting, Computer Telephone Integration, and object/relational database technologies.

Along with the "cutting edge" technologies mentioned above, CDS is being developed using an Internet-based development strategy. The Internet-based environment is currently under development and has the overriding goal of providing accurate and up to date access to all CDS development products. CDS's Internet environment includes integrated off-the-shelf products for system/software modeling, configuration management, problem reporting, and product distribution.

An early version of this Internet-based environment was used to perform the CDS Object Oriented Analysis Review (earlier this year). Reviewers were asked to perform their assignments with browser access to CDS documentation and object oriented models via the Internet at their local facility. Review attendance and issues were collected via Web pages and made available via the same Web pages to any interested reviewer or development team member.

OBJECT ORIENTED ANALYSIS AND DESIGN

CDS development team originally selected Rumbaugh's Object Modeling Technique (OMT) and Jacobson's Use Cases for CDS. During the period leading up to the initial CDS review, OMT and Use Cases were combined along with the Booch method to form the Unified Modeling Language (UML). UML was also adopted as a standard by the Object Management Group in 1997.

UML, the next generation object oriented modeling language solved some of the inherent issues of combining independent, but complemetary, techniques. UML was adopted by the CDS development team with a minimal amount of convesion effort during preparation for the CDS Object Oriented Analysis Review.

Figure 3 is the CDS Context Diagram and presents the users (people) and systems (POIF, PPS, etc.), along with data flow direction (arrowheads), that define the environment in which CDS must execute. Users and systems interacting with CDS are considered actors and are represented by UML as stick-people in Figures 3 and 4.

Figure 4 presents the Use Cases for each actor during the CDS Operations Mode. CDS has multiple modes each with their equivalent Figure 4. The ovals in the CDS Operations Mode Use Case represent specific behaviors of CDS. These behaviors are then detailed individually to specify the system operational requirements.
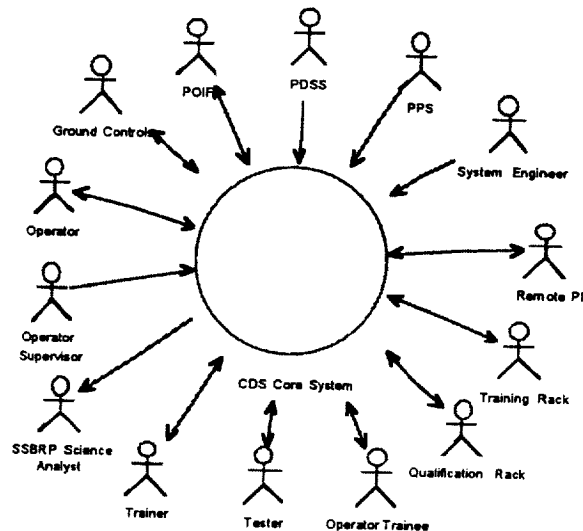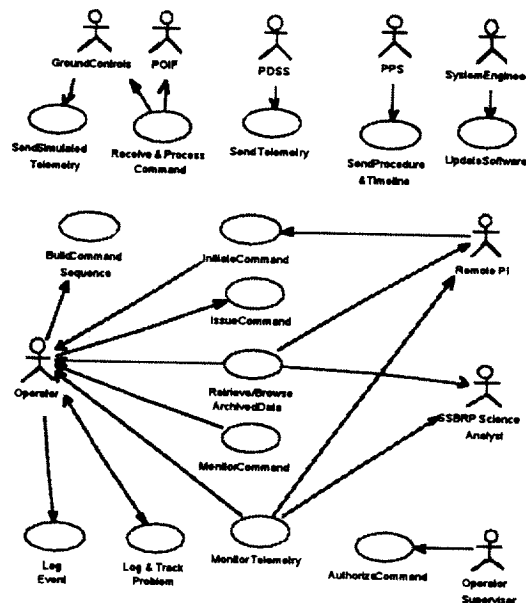

Figure 3 - CDS Context Diagram

Figure 4 - CDS Operations Mode Use Case

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Using UML has allowed the CDS developers to specify in a very clear and simple representation the functional capabilites to the "real customers" of CDS, the users. A development benefit is the relatively easy translation of these system behaviors to a CDS architecture.

UML usage for CDS is detailed further in SpaceOps98 paper 4c005 "SSBRP Communicaation & Data System Development using the Unified Modeling Language (UML).

Software prototyping and object oriented techniques are very compatible because both focus on the users needs for the system under definition. The CDS development team has produced a number of software prototypes prior to the CDS Object Oriented Analysis Review; and, plans to continue the prototyping effort.

TECHNOLOGY UTILIZATION

CDS implementation strategy has specified a number of technologies required during development. Some of these technologies are off-the-shelf while others require a development effort. A short discussion of some of the more significant technologies follows.

In moving from the more costly point-to-point communication approaches to an Internet-based communication solution security becomes a major concern. CDS is considering network, computer, and data security from the outset of CDS development as insurance that the developed system will meet or exceed externally specified as well as internally generated security requirements. The security component of CDS will be built in, not patched on.

Anyone who has purchased a safe recently will understand, security is measured by time required to break in. Given time any safe can be compromised. Therefore network, computer, and data security have a continuing security administration component, not just a development component.

Obviously CDS security implementation details will not be discussed in any open forum, but the CDS Security Policy development approach is described in SpaceOps98 paper 5d004 "Security For Multimedia Space Data Distribution Over The Internet".

The non-human life sciences research community supported by SSBRP relies heavily on the experiment's specimen for data. Although some biotelemetry data are expected to be available from implanted sensors, for the most part high resolution still-frame and motion-video will be used to enhance the researchers knowledge of the state of the experiment. Motion-video also allows the UOF ground operators to reduce crew time (very limited on-orbit resource) required to meet specimen well-being requirements.

Experiment and operations multimedia data, that include still-frame and motion-video, will be captured, digitized, and compressed on-orbit. Consequently, CDS does not need an analog video handling or distribution element within the UOF or to the remote researcher facility. Video will be stored and distributed in compressed form then uncompressed at the point of display either within the UOF or at the remote researchers facility. Multicast network protocols are being considered for both internal CDS and remote researcher multimedia data distribution.

Reducing the staff required to process the magnitude of data captured on-orbit and returned to the UOF was a major consideration in establishing an Internet-based data distribution strategy. CDS has established the "come and get the data at your convenience" strategy for the remote researcher. The intent of this strategy was to not only reduce the staff required to produce requested data products, but to reduce the pre-launch planning as well.

As an additional benefit to this approach, CDS can animate a researcher's digital data both within the UOF and at the remote researchers facility using JAVA and related technologies. This also allows the CDS development team to leverage internal UOF software development with external data distribution software and remain platform independent.

Additional information concerning the use of JAVA and the other Internet-based products may be found in SpaceOps98 paper 5b002 "Real-time Payload Control and Monitoring on the World Wide Web".

CDS DESIGN OVERVIEW

The UOF at Ames will be housed in several dispersed buildings on-site. To accommodate the security issues of an operations center, an isolated network structure independent of the Ames institutional network was implemented. The CDS network consists of a Fiber Distributed Data Interface (FDDI) backbone and multiple FDDI subnets. An "off-line" Ethernet network is currently being considered to support terminal servers and other administrative functions. Figure 5 presents the FDDI connectivity of CDS at Ames.

The CDS development team selected FDDI as the backbone and subnet structure because of FDDI's bandwidth for multimedia networking and the availability of FDDI network cards for CDS workstations and servers. The FDDI backbone, Flight Operations Area subnet, and system development subnet have been implemented for two years and support current CDS prototyping and development activities.

The demarcation point to the NASA Integrated Support Network (NISN) for Ames is housed in the Gateway Building. Connectivity is then extended to the Flight Operations Area subnet and other supporting subnets using the CDS backbone.
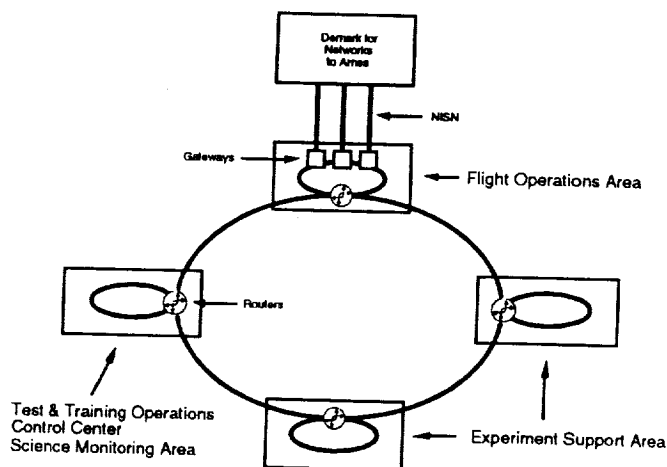

Figure 5 - CDS's Isolated FDDI Network

CDS is in the initial design phase of the development life cycle. Since CDS will support SSBRP on-orbit systems being developed and deployed over a number of ISS assembly launches, a phased design and implementation approach was selected. The initial development phase will be completed to support ISS Utilization Flight 3 and is identified in development schedules as the CDS Initial Operating Configuration (IOC). CDS Final Operational Configuration (FOC) aligns with ISS Utilization Flight 7 and will support the completed deployment of the major SSBRP on-orbit systems.

Figure 6 is the initial CDS configuration. Although not all the CDS network, storage, workstations, and servers in Figure 6 are currently in place, the FDDI backbone and development subnet are implemented with sufficient representative hardware and software to be used for CDS development and prototyping activities.

Some of the hardware in the CDS initial configuration was knowingly delayed to take advantage of rapid technology evolution and cost reductions. A good example of this is the mass storage unit of the Flight Operations Area. CDS mass storage requirements are estimated to be 4 Tera-Bytes of on-line data and digital video for a 120 day period. Being able to delay acquisition of this hardware should result in acquiring new and better technology at a lower cost.

Using Figure 6 as a conceptual CDS architecture, the following discussion applies as the overall CDS design strategy. CDS will integrate commanding, telemetry, and planning into a single system. Each of these major functions of an operations center relies on information from the other functions. CDS is planning to take advantage of these dependencies to design a more effective system and user

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interface. The goal is to reduce operator staffing requirements using the same concept used in system development where doubling the work force does not half the development time.
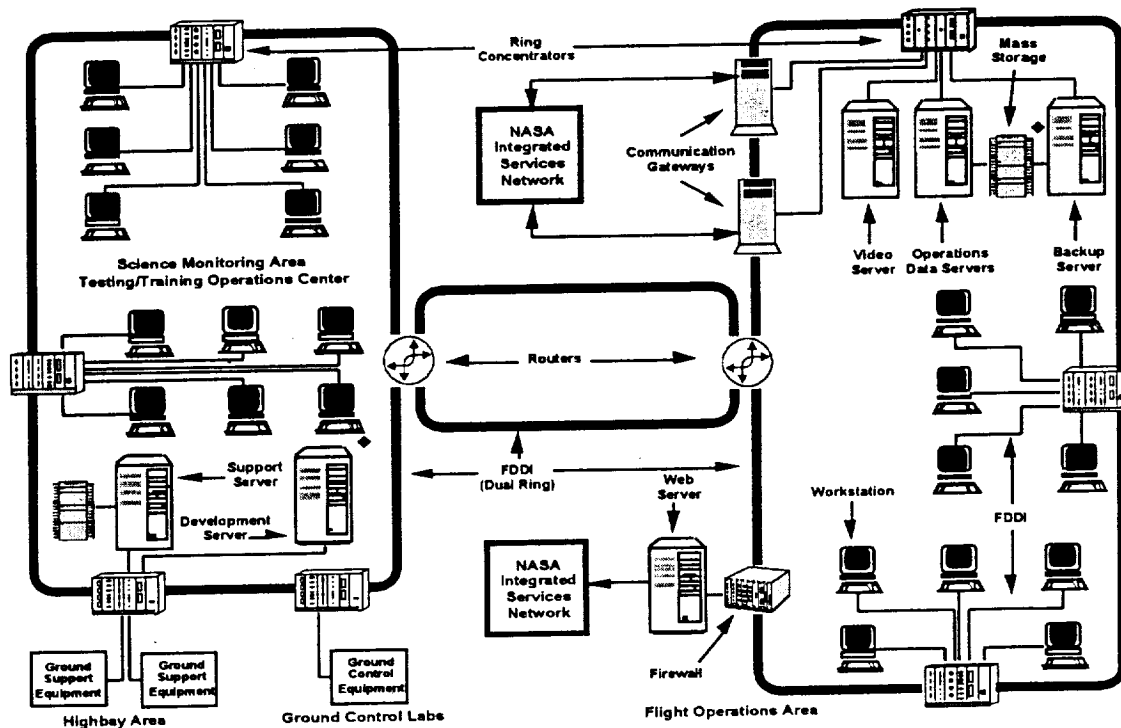

Figure 6 - CDS Initial Configuration

Currently the most well-defined of the trilogy of CDS functions is the telemetry processing. CDS receives Consultative Committee for Space Data Systems (CCSDS) packets from the ISS via the Payload Data Services System at MSFC. At CDS receipt of the CCSDS real-time data packets, the packets are processed; and, then only forwarded to the operator positions requiring the specific data. Additionally, the data is forwarded to any researcher currently on the Web server that requested the data. This distribution scheme includes multicast digital video. The real-time CCSDS data packets are also forwarded to a database system for later retrieval and analysis.

CCSDS data packets that arrive at CDS out of sequence, or were stored in transit, are sent directly to the CDS database for later retrieval. Since CDS uses data generation time as the storage ordering mechanism, CDS inherently time orders all stored data for future access. Retrieval of stored telemetry data may be accomplished by a CDS operator and/or researcher resident in the UOF or at their remote facility.

CDS commanding and planning functions are still in the definition stage and therefore not presented here.

CONTINUING ACTIVITIES

A series of CDS Object Oriented Design Reviews are scheduled to begin late this year and continue into 1999. In parallel to the software design process, the CDS network design is being completed along with finalizing the CDS Security Policy. Concurrently to the software and network design activities, the CDS development team members will continue to evaluate technologies that may be applicable to CDS and implement prototypes as appropriate.